

Galvo Scan Heads for Precision Laser Welding in Manufacturing

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Precision laser welding in manufacturing requires fast, accurate positioning of the laser beam on the part. When paired with fiber lasers, galvo scan heads can minimize point-to-point positioning times, shaving seconds off cycle times on parts with multiple weld locations. Ideal for use in welding field sizes up to 100 x 100 mm, galvo scan heads are suited to small medical devices, battery packs and electrical interconnections. This article focuses on the application of 2D galvo scan heads in precision laser welding processes.

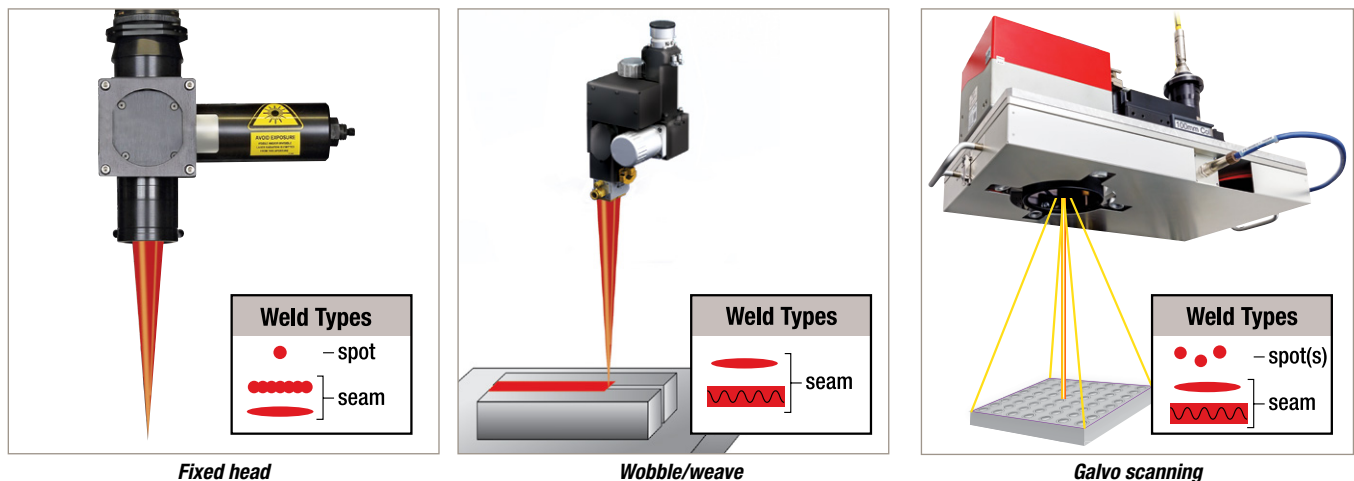


Figure 1. Laser beam delivery options

Laser beam delivery basics

The hardware components used to deliver a laser beam from the source to the workpiece are critical for performance and include mirrors, shutters, collimators, fibers and focus heads. There are three primary laser beam delivery options available, as shown in **figure 1**.

- Fixed focus heads are usually mounted to a fixed vertical Z-stage, and the parts are moved to set points where the laser is fired. Due to the mass of the stages, tooling and parts, this is a relatively slow process, but offers excellent positioning capability.

- Wobble/weave focus heads are also typically mounted to a vertical Z-stage. However, rather than a fixed beam at the output, a small oscillation wobbles the beam back and forth in a defined pattern. This wobble helps increase the size of the melt pool and join parts that have lower manufacturing tolerances for part fit-up. As with the fixed focus head, the parts are moved to set points where the laser is fired, creating the weld.
- Galvo scan heads direct the laser beam using two mirrors through an f-theta lens, focusing it in an X, Y area. The galvo scanning head is typically mounted on a programmable Z stage to adjust the working height of the head and maintain focus on the part. The beam can be steered to any location within the field, which, for precision laser welding applications, is typically around 100 x 100 mm. Because the position in the X, Y field is related to a small motion of the mirrors, a 25 mm move takes just a few milliseconds to advance, settle and be ready for welding.

Galvo scan heads facilitate quick and accurate point-to-point positioning

A galvo scan head consists of two mirrors, each mounted on very small rotary motors, called galvanometers, or galvos for short, which, in turn, are mounted orthogonally to each other such that the rotary motion of the two mirrors translates to linear motion in the X- and Y-axes. The small size of the motors provides high-speed positioning, short settling times and high acceleration/deceleration, which are ideal for high-speed, short-distance motion. **Figure 2** shows the design and composition of a typical galvo scan head.

Design / Composition

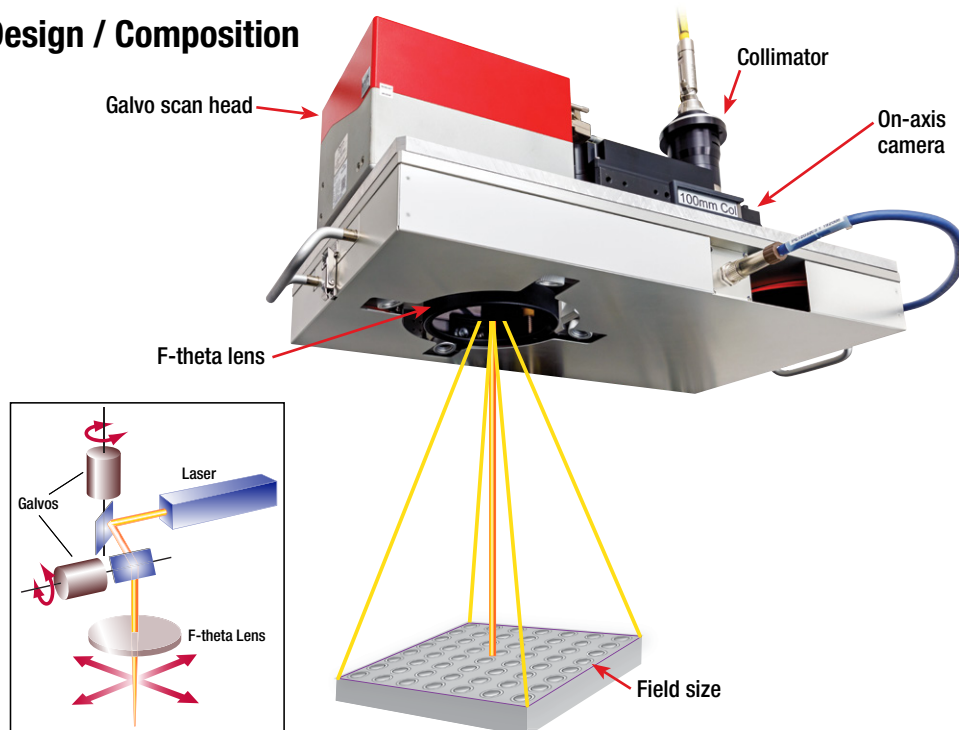


Figure 2. The principle of galvo welding

The galvo scan head's primary advantage over a fixed head stems from the fact that a fixed head requires high precision and repeatable motion stages that move the part and necessary tooling (with their accompanying mass) under the head. The momentum required for the stages

and tooling slows down both the scanning speed and acceleration necessary for motion in different directions. By contrast, the two mirrors in the galvo scan head are lightweight and can be moved quickly because they are small and not moving much mass. Additionally, just a small rotation of the mirror is comparable to a large linear movement. The time needed for a galvo beam to move from one corner to the next in a 100 x 100 mm field can be measured in milliseconds. Compare that with the time it takes to move parts for fixed focus heads, which can take up to a second or longer.

Galvo beams move very quickly over field sizes up to about 100 x 100 mm, making them best suited for spot and seam welding of smaller parts. The flexibility in programming the beam location and the speed at which the beam can move also provide the capability to wobble the beam on top of the weld path to increase the melt area for butt weld and fillet weld situations or to increase the weld contact area in a lap weld situation. In other words, if the weld path is in X direction, the wobble is the transverse Y direction, providing additional width to the melt pool, thereby creating a larger weld nugget.

In industry, galvo scan heads are an excellent tool for assembling small battery packs, where each cell must be joined. They are also ideal for electrical interconnect applications, especially when joining two to three relatively close points for plugs or connections. Other typical applications include spot welds for a tray of parts, welding small medical devices and seam sealing of microwave and RF packages for the aerospace industry. **Figure 3** shows a few of the typical patterns for galvo scan laser welding.

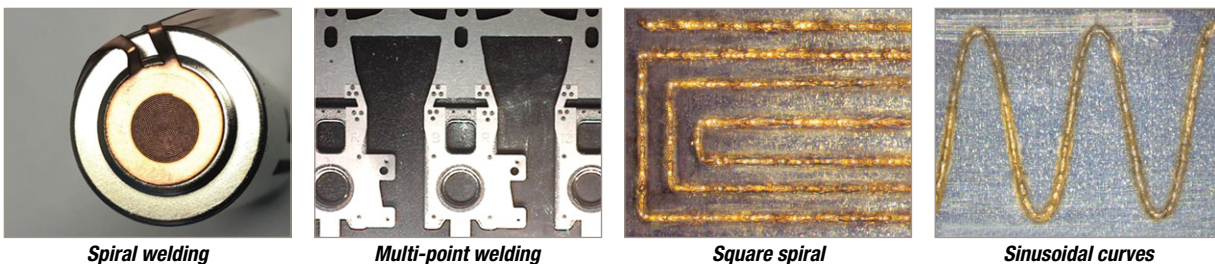


Figure 3. Examples of spot and seam welding using a galvo beam

Although there are several advantages, there are also some limitations for galvo scan laser welding. First and foremost, the scan field size is limited by the optic selection. For welds that extend beyond the field size, additional motion is required to move the beam to the desired locations. Second, galvo scanning heads handle welds primarily in a 2D plane. For some, a third dimension is added to quickly adjust the focal height, but if the weld wraps around a 3D part, additional motion is required.

Integrating galvo systems

AMADA WELD TECH has many years of experience designing laser systems and determining the best beam delivery to achieve desired spot size, minimize power loss, optimize throughput and ensure ease of maintenance. For the past decade, we have integrated galvo scanning solutions for the medical device, battery, electronic and aerospace industries.

To determine the right equipment, one must consider both the laser specifications and which galvo scan head is best suited, and the process requirements.

From the laser specification side, the divergence of the laser beam, wavelength and laser power all need to be considered in order to select the correct optics and galvo scanning head to deliver the beam to part.

- Divergence of the beam (combined with the collimator) determines the size of the aperture of the scan head and the optics required. The larger diameter typically results in a smaller field size.
- Wavelength determines the coatings for the optics.
- Laser power determines whether the head needs air-cooling, water cooling or both.

From the process side, field and spot size are the most important aspects, but these are often in conflict because it is desirable to have a large field and often necessary to have a small spot size. The field size is related to the f-theta lens. The larger field size results in a larger spot size.

- Field size—For welding applications and consistency across the entire field, a telecentric lens is preferred. This limits the field size to approximately 100 x 100 mm.
- Spot size—The desired spot size depends on the material, the process and the welding success criteria.

AMADA WELD TECH has selected a few standard configurations for each laser type to maximize the field size and spot size for welding applications.

Programming of the galvo-based systems is typically undertaken with a graphical software that allows a variety of shapes and motions to be easily programmed in or even imported from a DXF or other CAD drawing file. The shapes are then programmed with laser power, speed and frequency (if pulsed) at the most basic levels. The control card handles the timing between the laser firing and the galvo motion.

When integrating the galvo and laser, an additional consideration is the control and communication protocol that will be used. The galvo scanning head and laser are typically subcomponents of a larger system and may be controlled through an external PLC. Common communications protocols include serial (RS-232 or 485) or remote API commands through TCP/IP and EtherNet/IP™ fieldbus.

In addition, there is a variety of optional features, including vision and process monitoring systems, air knives, cover gas, lighting, autofocus and mounting configurations.

Transitioning to galvo scan laser welding

Galvo scan laser welding is transitioned to from either a fixed focus laser welding technology, wobble/weave welding technology, or other welding technology. As with any change, it is important to understand the capabilities and limitations, in addition to additional safety concerns.

Transitioning from fixed focus head to galvo scanning head

These two technologies are similar in terms of potential transitions. The galvo scanning head opens up a means to achieve rapid point-to-point positioning and seam welding, though it is limited to the area of the galvo field. If the required processing field is beyond that area, then motion to the new area needs to be considered. The technologies share the same requirements for part fit up and material selection. Safety requirements for both are also the same since they use the same type of laser source.

Transitioning from a wobble/weave focus head to galvo scanning head

These two technologies are the most similar in terms of potential transitions. The wobble/weave head is often built based on galvo technology, but in the design, the amplitude of the wobble is limited to a few millimeters (focal length dependent). The strength of the wobble/weave head is for seam welds, but individual spots outside the small area cannot be addressed without additional external motion. The galvo scanning head can do the same seam weld in addition to other spot welding, however, that flexibility comes at a price – and when the seam is longer than the field size, this poses additional challenges. The technologies share the same requirements for part fit up and material selection. Safety requirements for both are also the same since they use the same type of laser source.

Transitioning from other welding technologies to galvo scanning head

Changing from a non-laser technology to laser technology brings a range of different and new considerations, including a new energy source that requires proper protective gear and a non-contact welding process that demands proper tooling to achieve a good fit-up between parts to weld. The design of the part and weld path often needs to be reconsidered to take advantage of the galvo speed and remove potential geometrical limitations to access the weld location.

Considering galvo scan heads to extend traditional motion or robotics

Galvo scan heads are worth considering to facilitate quick and accurate point-to-point positioning for a variety of laser welding applications. They are an ideal solution for extending the traditional motion of X, Y tables or robotics. The high repeatability lends itself to automation. When designing a manufacturing process, having processes that can be timed appropriately leads to decreased cycle time and predictable throughput.

Summary

Galvo scanning technology offers many benefits for precision laser welding. For suitably designed parts, this technology can drastically reduce cycle times and improve production throughput for point-to-point welding and seam welding applications. Its quick motion can be used to quickly place multiple welds and also helps to overcome manufacturing tolerances in part fit-up. Galvo scanning is easily integrated into laser welding work cells and automated production lines, which is seeing it employed in an ever-increasing array of applications.



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